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Latitudinal variation of ozone in India

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Abstract A critical analysis has been made on latitudinal and longitudinal variations of ozone in India It reveals that the concentration ally i
nation for the variation of ozone with latitude is also presented

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Ozone is a minor constituent in the atmosphere It plays an important role in chemical kinetics of the atmosphere and saves lives by absorbing UV rays from the sun There are three types of UV region UV-A, UV-B, and UV-C Wavelength in the range 200-280nm is known as UV-C region It is completely absorbed by O_3 Wavelengths in the range 280-315nm called UV-B region are partially absorbed, but not completely, while UV-A of wavelength (315-400nm) are absorbed weakly by O_3 and are therefore more easily transmitted to the Earth's surface [1]

Increased UV-B fluxes yield higher tropospheric concentrations of HO_x ($OH+HO_2$) [2-5], corresponding faster loss of CH_4 [6], global decrease in CO concentration [7] and enhanced H_2O_2 concentration [8-10], causing environmental pollution The UV-B sunlight has an adverse effect on mechanical properties on synthetic (plastic) and naturally occuring polymers (woods) limiting their useful life [11]. It has undesirable acute effects on human health including sunburn, skin pigmentation consisting of immediate pigment darkening (IPD) and neomelanogenesis [12] and skin cancers consisting of squamous cell carcinoma (SCC), basal cell carcinoma (BCC) and cutaneous malignant melanoma (CMM) [13,14] It affects the cornea, lens, vitreous humour and the retina of an eye causing cataract, photokeratitis, characterized by reddening of the eye ball, gritty feeling or severe pain, photophobia and twitching [15]

The recent scientific assessment of global warming by the IPCC, qualifies the impacts of a wide range of radioactive forcing agents, including green house gases, aerosols and other forcing mechanism It has been observed that after CO_2 and CH_4, O_3 is the most important driver of human induced climate change [16] through 2100. Dobson *et al* [17] observed that the surface temperature of earth is closely related to stratospheric ozone concentration Midya *et al* [18] observed that relative humidity is directly related to ozone concentration of stratosphere over Kolkata Recently long-term ozone analysis shows an increasing trend by 1 – 2 % per year, in the Northern Hemisphere causing greater global warming (18 % of the total global warming) comparable to the increase of CO_2 [19] So the climatic conditions of the Earth, chemical kinetics of the atmosphere, environmental pollution, human health, lives of plants etc. are controlled by atmospheric ozone

Ozone studies have already been done by different investigators [20] at the different stations throughout the world Ozone is not equally distributed in troposphere, stratosphere

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and mesosphere [21] The concentration of ozone gradually increases from upper troposphere, attains maximum at an altitude of 25 – 30 km and then gradually decreases [22]. The seasonal variation of total ozone differs from place to place At Halley bay (76^{0}S, 27^{0}W), a British Antarctic survey station, maximum ozone concentration occurs during the months of January and February, then gradually decreases, attains minimum during September – October and then gradually increases [22] But for Indian region for the latitude range 8 – 35° N, concentration of O_3 gradually increases for the month of January, attains maximum during May – June, then gradually decreases and attains minimum for the month of December [22] In this paper, the latitudinal variation of ozone concentration in India is presented

2. Data analysis and results

Ozone concentrations of different stations of different latitudes are obtained from Internet website http //jwocky gsfc nasa.gov Monthly mean ozone concentrations are calculated from daily average value of ozone in Dobson unit (DU) for different stations in India, namely, Trivandrum (8 25° N, 76 9° E), Kodaikanal (10° N, 77° E), Bangalore (13° N, 77 5° E), Madras (13° N, 80 1°E), Hyderabad (17.25° N, 78 5° E), Poona (18° N, 73 6° E), Bombay (19° N, 72 9° E), Nagpur (21° N, 72 9° E), Dumdum (22 5° N, 88 5° E), Ahmedabad (23° N, 72 6°E), Varanasi (23 5° N, 83° E), New Delhi (29° N, 77° E) and Srinagar (34° N, 74 8° E) Yearly mean concentrations for each station are calculated from monthly mean values from 1979 – 1998

The variations of yearly mean ozone concentrations with latitude from 8 25° N to 34° N for every year from 1979 – 1998 have been critically analysed Figures 1a and 1b show the latitudinal variation of yearly ozone concentration in Dobson Unit (DU) from 8 25°N to 34°N for the year 1982 and 1996, respectively. It has been observed that ozone concentration gradually increases with increase in latitude for every year, but at different rates The rates of increase of ozone concentration per degree latitude vary from 0 1992 DU to 1.4302 DU The rate is maximum for the year 1982 and minimum for the year 1996 The average rate of increase is 0.906 DU per degree latitude The equations of ozone concentration with latitude best fitted for the above two years are as follows and shown in Figures 1a and 1b

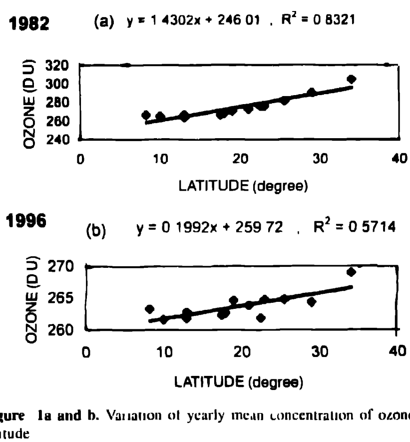

Figure 1a and b. Variation of yearly mean concentration of ozone with latitude

$$[O_3] = 1\,4302\,\text{Lat} + 246\,01, \quad R^2 = 0.8321,$$

$$[O_3] = 0\,1992\,\text{Lat} + 259\,72, \quad R^2 = 0\,5714,$$

where $[O_3]$ represents the concentration of ozone and l represents the geographical latitude of the station

The variations of yearly mean concentrations of ozone with longitude are oscillatory with little decreasing trend for each year (*eg* 1980) except the year 1992 shown in Figures 1c and 1d has been observed that the maximum ozone concentration occurs at a definite longitude of 74 8° E for each year

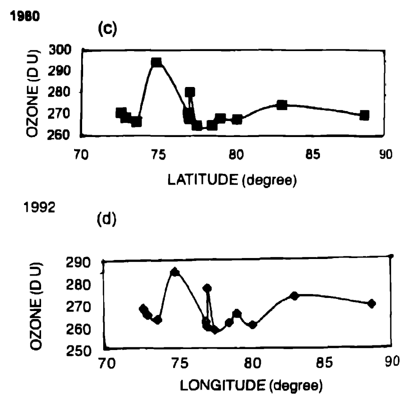

Figure 1c and d. Variation of yearly mean concentration of ozone with longitude

Latitudinal variations of monthly mean ozone concentration for each month during the said period have also been analysed It has been observed that the variations of monthly mean ozone with latitude has an increasing tendency for each month except the month of August shown in Figure 2c The rates of increase of ozone concentration vary from 2 336 DU to 0.1955 DU per latitude. The rate is maximum for the month of February and minimum for the month of July, shown in Figures 2a and 2b The variations of ozone concentration with latitude for the above two months are given as follows

$$[O_3] = 2\,336\,\text{Lat.} + 213\,3,$$

$$[O_3] = 0\,1995\,\text{Lat} + 276\,11$$

The variation of monthly mean ozone concentration with latitude obeys the following equation

$$[O_3] = -0.0177\,\text{Lat} + 278.58$$

Hence, the rate of decrease of ozone concentration with latitude for the month of August is 0.0177 DU per each latitude

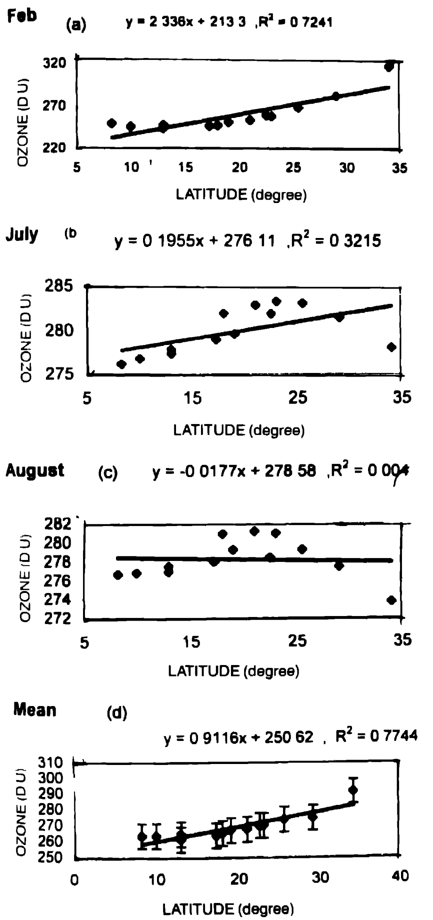

Figure 2. Variation of monthly mean concentration of ozone with latitude.

The variation of the yearly mean concentrations of ozone with latitude during the period 1979 – 1998 is also represented in Figure 2d. It reveals that the concentration of ozone increases with increase in latitude. The rate of increase is 0.9116 per each degree latitude.

3. Discussion

In 1930, Sydney Chapman [23] postulated the following process of ozone formation

$$O_2 + UV \longrightarrow O + O,$$

$$O + O_2 + M \longrightarrow O_3 + M$$

So the formation of ozone is directly governed by the densities of O, O_2 and N_2 in atmosphere. Again, the densities O, O_2 and N_2 are directly proportional to the air density [24]. Thus, the variation of air density may play an important role in the variation of ozone concentration at different places and different times. Jacchia [25] has given a number of relations from which latitudinal variation of air density can be obtained. The latitudinal density variation in the log of air density is given by the following equation [25]

$$\log\{\Delta[\text{Air}]\} = \Phi/|\Phi|\; SP \sin^2 \Phi\,,$$

where, Φ represents the latitudinal angle and

$$S = 0.014\,(Z-91)\exp\left[-0.0013(Z-91)^2\right]$$

$$P = \sin\,(2\Pi\Psi + 1.72)\,,$$

where, Ψ = fraction of year = (t –Jan 1)/365, t in days and Z represents altitude in km.

Air density Δ [Air] is calculated for the latitude range 0^0N-60^0N. The value agrees fairly well with the measurement of air density by Davis and Smith [26].

Ghosh and Midya [24], has showed the latitudinal variation of air density, Δ [Air] both for Southern and Northern latitude for 0^0– 60^0. It has been observed that Δ [Air] increases with increases in latitude. So we can expect that ozone concentration should increase with increase in latitude which has been confirmed from our analysis. Figure 3 shows the variation of

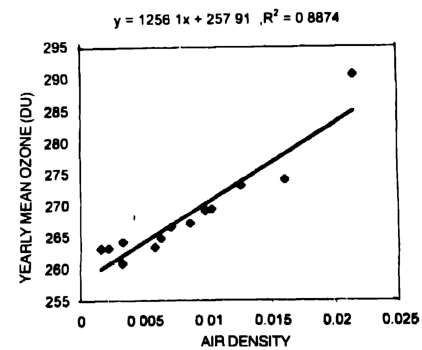

Figure 3. Variation of mean of yearly mean ozone concentration with air Density.

yearly mean ozone concentration with the variation of air density for latitude range 0^0N to 60^0N Air density [Air] is obtained from the calculated value by Ghosh and Midya eq (1) of ref [24]. We obtain a linear relation of the variation of ozone concentrations for the said period and air density, shown in Figure 3 and the equation is as follows

$$[O_3] = 1256\ 1\ \mathrm{Lat} + 257\ 91$$

Ghosh and Midya [24] also showed that the air density is minimum at the equator and it increases with increase in latitude, so it is expected that the O_3 concentration will be minimum at the equator and will increase with increase in latitude which may be verified by the experimental measurements of ozone concentrations at different latitudes in Southern Hemisphere

4. Conclusions

Yearly mean concentration of ozone gradually increases with increase in latitude from 1979 to 1998, but at different rates It has been also shown that monthly mean concentration of ozone increases with increase in latitude for each month at different rates except the month of August. The variation of yearly mean ozone concentration with different longitude is oscillatory during the period 1979 to 1998 It has been also observed that the maximum ozone concentration occurs at a definite longitude The variation of ozone concentration with latitude may be explained by the variation of air density

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